# *Cover Letter*
# *Draft for TOC Review*

**RES 14**

June 4, 2003

**TO:** **Principals of the Consent Decree and Other Interested Parties** (list attached)

**RE**: **A Water Quality Exceedance** from Interim Levels in the Arthur R. Marshall Loxahatchee Wildlife Refuge, July 2002

The attached letter report documents an exceedance from the total phosphorus (TP) Interim Levels for the Arthur R. Marshall Loxahatchee Wildlife Refuge (Refuge) set forth in the 1991 Settlement Agreement. Specifically, the July 2002 geometric mean TP concentration of 11.2 ppb exceeded the predicted TP level (9.7 ppb) by 1.5 ppb.

The report summarizes data on an exceedance in the monthly geometric mean within the 12-month period between August 2001 and July 2002, and provides information on contributing circumstances. Members of the Technical Oversight Committee (TOC) and other interested parties discussed this water quality information at their February 11, 2003 meeting and requested staff to prepare a report for the next committee meeting (June 3, 2003) to evaluate the exceedance and provide recommendations. At the June 3, 2003 TOC meeting, the members provided comments which have been incorporated into the attached letter report.

**Contributing Circumstances: Evaluation** by District staff and discussion by the TOC revealed several factors that could contribute to this exceedance:

- A dry period in May 2001 ended with a rapid increase in water depth from mid-June to mid-July, 2002.
- Increases in depth were accompanied by increases in phosphorus inputs to the Refuge although no immediate effect of these inputs was apparent in the monitoring data.
- Phosphorus levels actually dropped 2.2 ppb between June and July, while the calculated Interim Level dropped 6.3 ppb, leading to the 1.5 ppb exceedance of the predicted value.
- Phosphorus levels have been below the Interim Level for the eight months following the exceedance (data through March, 2003)
- Circumstances of this event follow a pattern seen in prior exceedances in the Refuge.

**Recommended Action:** Based upon the TOC's review of the July 2002 exceedance and relevant circumstances, TOC recommends continued implementation of phosphorus controls, compliance monitoring and data review.

If you have any questions or comments on this water quality exceedance and the attached letter report, please feel free to contact me (561 682-2200), Garth Redfield (561-682-6611) or Tim Bechtel (561-682-6392).

Sincerely,

Naomi S. Duerr, P.G.
Director, Department of Environmental Monitoring and Assessment

NSD/grs

Attachments: Letter Report with Attachments
Distribution List

# *Draft for TOC Review*

June 4, 2003

**TO: Principals of the Consent Decree and Other Interested Parties** (list attached)

**RE: A Water Quality Exceedance** from Interim Level in the Arthur R. Marshall Loxahatchee Wildlife Refuge, July 2002.

**Background:** This letter report was requested by the Technical Oversight Committee (TOC) at their February 11, 2003 meeting. The TOC asked that Garth Redfield, TOC Chair, and Tim Bechtel, Supervisor of the South Florida Water Management District's (District) Data Evaluation and Reporting Unit, provide a letter documenting an exceedance from the total phosphorus (TP) Interim Levels for the Arthur R. Marshall Loxahatchee Wildlife Refuge (Refuge) as set forth in the Settlement Agreement (1991, Case No. 88-1886-CIV-HOEVELER). The TOC requested us to summarize key facts relevant to determining whether these occurrences are due to "error or extraordinary natural phenomena" or represent a violation of the Settlement Agreement's Interim Level.

Appendix B to the Settlement Agreement specifies that two or more exceedances of the interim or long-term levels of total phosphorus in a 12-month period must be reviewed by the TOC as a potential violation of the Settlement Agreement. With information from this review and recommendations from TOC members, the TOC Principals of the five settling parties will then decide what actions may be appropriate under the Settlement Agreement.

**The TP Exceedance**: A rapid rise in Refuge stage due to inflows and local rainfall resulted in a geometric mean TP concentration for July 2002 of 11.2 ppb which is 1.5 ppb higher than the calculated Interim Level of 9.7 ppb. The 'Interim TP Level' for the Refuge became effective February 1, 1999. The Interim Level for TP was first exceeded within the 12-month period in October 2001. A second exceedance in the 12-month period occurred in July 2002. This letter concerns the second exceedance. Evaluations of two earlier exceedances were the subject of two letters to the Principals dated July 14, 2000 and October 24, 2001. Based upon their analysis of the data and relevant circumstances, TOC recommended no actions on these exceedances.

Geometric mean concentrations of TP, applicable TP limits, and water depths (stages) in the Refuge for the January 2001 through December 2002 period are presented in the April, 2003 Quarterly Water Quality Conditions Report, posted on the TOC website: http://www.sfwmd.gov/org/ema/toc/index.html. An updated version of these data through March 2003 for the Refuge is provided in the attached **Table 1**. TOC members and interested parties were provided with water quality information, including data on the July 2002 and October 2001 exceedances, in quarterly reports to the TOC for the February and June 2003 meetings. The time lag between data collection and evaluation

by the TOC normally runs 6 to 9 months due to typical field collection, laboratory analyses, quality control and data reporting times. The District is currently in the process of implementing a new system of reporting that will shorten this lag time substantially and provide updated data on the TOC website on a monthly basis.

The July 2002 excursion is summarized below in the table below:

| **Month 2002** | **Geometric Mean** (ppb TP) | **Interim Level** (ppb TP) | **Long-Term Level *** (ppb TP) | **Average Stage (ft.)** |
|---|---|---|---|---|
| July | **11.2** | **9.7** | 8.3 | 16.82 |

***** Note that the Long-Term Level becomes effective December 31, 2006.

**Contributing Circumstances:** Discussion at the February 2003 TOC meeting and subsequent evaluation of Refuge monitoring data by District staff revealed proximal circumstances that should be considered when interpreting these data and deciding upon appropriate recommendations to the Settling Parties. Hydrological and nutrient conditions during June and July 2002 are particularly important to consider.

Data on daily stage levels, inflow volumes, rainfall amounts, TP loads, and TP concentrations are provided in **Table 2**. The location of inflow points in the Refuge is given in the attached Figure 1 and the location of monitoring sites is shown on Figure 1 of each Settlement Agreement report to the TOC.

Based on data from S5A, over 17 inches of rain fell in June 2002 and the first half of July 2002 prior to Refuge sampling on July 15 and 16, 2003. This significant local rainfall was part of a pattern of very heavy rainfall in the central and northern sections of the District. The July 11, 2002 Water Conditions Summary to the Governing Board noted that rainfall in June and the first one-half of July was over 1.5 times normal and produced rapid increases in water levels in Lake Okeechobee and the Water Conservation Areas. This regional and local water input resulted in increased inflows to the Refuge in mid-June, and combined with direct rainfall, raised water stages in the Refuge from an average of 15.04 ft. in May to 16.82 ft. in July 2003 (**Table 1**). It is important to note that both the July 2002 and October 2001 events occurred during periods when water levels increased rapidly after a period of low water levels. In fact, since the Interim Level went into effective in February 1999, 6 of 7 exceedances were associated with increases in stage from the previous month of 0.5 to 1.3 feet. This pattern does not appear to be random, and suggests that marsh TP levels do not respond as quickly to the dilution effects of increasing stage as is predicted by the equation used to calculate the Interim Level.

The data in **Table 2** also show phosphorus concentrations entering the Refuge during the June to July 2002 period of increasing inflows. For a brief period from June 21 to 27, 2002, G300 and G301 discharged relatively small volumes of untreated water into the L7 and L40 canals in the Refuge. From mid-June to mid-July, G302 contributed high TP concentrations and flows to STA-1W. Inflows to the Refuge from STA 1W through G251

and G310 showed much lower phosphorus concentrations after treatment by the STA and contributed substantial volumes particularly during the period from June 18 to July 16, 2002. The STA-1W inflow concentrations during this same period are consistent with the annual mean for WY 2002 of 38 ppb (2003 Everglades Consolidated Report, Chapter 4A). Inflows to the Refuge from the ACME basins were rich in phosphorus but flow amounts were much smaller than other inflows.

It is also informative to examine monthly data from the 14 individual stations in the Refuge (see **Table 3)** for the period between January 2001 and December 2002. Six stations showed increased TP levels in July 2002 after experiencing very low water levels in the May to June 2002 period (LOX 3, 4, 5, 9, 10, and 11). This tendency was counterbalanced by 5 stations that experienced low water levels in the May-June timeframe and showed a decreased phosphorus concentration in July relative to June (LOX 6, 7, 8, 13 and 16). Considering the changes at all these stations and the inconsistent pattern seen in the three stations that did not dry out (LOX 12, 14 and 15), we see no obvious pattern of concentration change in Refuge sampling stations associated with proximity to the canal and inflowing nutrients, with the possible exception of LOX 4 (Table 3). **Therefore, variation in TP levels due to short-term, natural hydrological and stage dynamics appears to be the primary source of the July 2002 TP exceedance.**

**Longer Term Context of TP Inputs to the Refuge:** Major changes in TP loading and inflow concentrations to the Refuge have been documented with STA-1W and STA-2 in full flow-through operations. The concentration values in **Table 2** show the major effect that STA treatment has on TP levels; untreated STA inflow water via G302 recorded TP levels far above the 30 – 40 ppb commonly seen in treated STA-1W inflows to the Refuge via G 251 and 310. More reductions can be expected with the completion and full operation of STA-1 East and the additional enhancements to STA-1W contemplated in the Conceptual Plan. When all sources of water entering the Refuge during Water Year 2002 are combined, they have a median concentration of 38 ppb, about one-half the value observed for the 1978-2000 base period (Chapter 2, 2003, Everglades Consolidated Report).

Working in tandem with STA treatment, the EAA BMP Program has resulted in significant reductions in TP loading derived from the Everglades Agricultural Area. Data summarized in Chapter 3 of the 2003 Everglades Consolidated Report documents that EAA phosphorus loads have been reduced 55 % for Water Year 2002, compared to what would have entered the WCAs under similar rainfall periods prior to BMP implementation. Prior to the STAs and the EAA BMPs, approximately 90-100 metric tons TP per year entered the Refuge from the EAA. During normal flow years, implementation of EAA BMPs, and the effectiveness of STA-1W and STA-2 should reduce phosphorus loads from the EAA to the Refuge by about 85%, meeting the load reduction goals contemplated in the Settlement Agreement. In addition, STA-1 East will bring additional water into the Everglades system (via the Refuge) for hydropattern restoration.

**Conclusion:** The rapid rise in Refuge stage due to inflows and local rainfall caused the interim TP level to decrease dramatically from 16.0 ppb to 9.7 ppb between June and July 2002. While the geometric mean TP concentration during this time period decreased from 13.4 to 11.2 ppb, it nevertheless exceeded the interim TP level by 1.5 ppb. The sharp increase in stage shifted the calculated Interim Level for TP downward while the observed ambient TP levels held within the range of values commonly seen in the Refuge since 1994 during periods with similar water depths. This pattern of exceedances associated with sharp increases in stage has been seen repeatedly in the Refuge since 1999. There is no evidence of any field, laboratory or computational error involved in this event.

For the last eight months **(Table 1)**, TP levels have not only achieved interim levels but bettered the long-term levels not scheduled to go into effect until December 2006. Because there have not been two exceedances during the 12-month period ending March 2003, the Refuge is presently in compliance with the Interim Levels of the Settlement Agreement. Given the current TP levels, the hydrological circumstances discussed above (which are analogous to circumstances associated with the rapid rise in water levels seen in 1999, 2000 and 2001), the July 2002 TP exceedance is not indicative of any fundamental change in the nutrient status of the Refuge.

**Recommended Actions:** No actions are recommended at this time. Appendix B of the Settlement Agreement contemplates potential correction measures in the event the Interim or Long-Term TP Levels are not met in the Refuge. Long-term TP Levels do not go into effect until January 1, 2007. With regard to exceedances of Interim TP Levels, Appendix B (Page B-2) directs only that DEP implement control measures "to meet a maximum annual discharge limitation of 50 ppb for all discharges into the Refuge from the EAA." Outflows from STA-1W during the relevant time period averaged below 50 ppb. In addition, the District and DEP have continued to implement enhancements to the STAs to optimize performance and this process will continue through the Conceptual Plan. These facts and review of the above information, the incomplete implementation of the STA and BMP programs, and the discussion of these facts and findings with the TOC on June 3, 2003, no immediate actions appear to be warranted. TOC may wish to consider examining the predictive ability of the compliance equations in Appendix B of the Settlement Agreement during periods when stage increases rapidly.

Respectfully Submitted,


_____ _____

Garth Redfield, Ph.D. Timothy Bechtel, Ph.D.

Chief Environmental Scientist Senior Supervising Environmental Scientist

Environmental Monitoring and Assessment Department

## Distribution List for Electronic and Paper Copies

**Principals of the Consent Decree**

- Ernie Barnett, Director of Ecosystem Projects,
  Florida Department of Environmental Protection;
- Henry Dean, Executive Director,
  South Florida Water Management District
- Colonel James May,
  U.S. Army Corps of Engineers, Jacksonville
- Mark Musaus, Manager,
  ARM Loxahatchee National Wildlife Refuge
- Maureen Finnerty, Superintendent,
  Everglades National Park

**TOC Representatives**

- Garth Redfield, SFWMD
- Frank Nearhoof, FDEP
- William Baxter, USACOE
- Michael Waldon, USFWS
- Michael Zimmerman, NPS

**Other Interested Parties**

All persons on the TOC electronic mailing list as of June 4, 2003 were provided with an electronic file of this letter and were notified of its posting on the TOC website: http://www.sfwmd.gov/org/ema/toc/index.html.

CC Paper Copies:

Carrie Trutwin
Tim Bechtel
Naomi Duerr
Dee Azeredo
Kirk Burns
Doug McLaughlin
Chip Merriam

| Table 1. | Loxahatchee National Wildlife Refuge Total Phosphorus Compliance Tracking (updated from April, 2003 report with data through March, 2003). |
|---|---|

| Month - Year | Geometric Mean Concentration (ppb) | Interim Level (ppb) Effective 2/1/99 | Long Term Level (ppb) Effective 12/31/06 | Average Stage (ft,NGVD) | Number of TP Samples | Number of Stage Measure-ments |
|---|---|---|---|---|---|---|
| Apr-2001 | 11.5 | 21.4 | 16.9 | 15.48 | 6 | 3 |
| May-2001 | 18.3 | 0.0 | 0.0 | 14.88 | 2 | 3 |
| Jun-2001 | 15.1 | 0.0 | 0.0 | 15.42 | 9 | 3 |
| Jul-2001 | 11.4 | 17.2 | 13.8 | 15.82 | 11 | 3 |
| Aug-2001 | 10.0 | 10.1 | 8.6 | 16.74 | 14 | 3 |
| Sep-2001 | 9.6 | 11.1 | 9.3 | 16.57 | 14 | 3 |
| Oct-2001 | 8.8 | 8.3 | 7.2 | 17.24 | 14 | 3 |
| Nov-2001 | 6.6 | 8.3 | 7.2 | 17.46 | 14 | 3 |
| Dec-2001 | 7.5 | 8.9 | 7.7 | 16.99 | 14 | 3 |
| Jan-2002 | 6.4 | 10.4 | 8.8 | 16.69 | 14 | 3 |
| Feb-2002 | 7.8 | 10.7 | 9.1 | 16.63 | 14 | 3 |
| Mar-2002 | 7.3 | 11.5 | 9.7 | 16.50 | 14 | 3 |
| Apr-2002 | 7.5 | 15.6 | 12.7 | 15.98 | 11 | 3 |
| May-2002 | 10.0 | 0.0 | 0.0 | 15.04 | 3 | 3 |
| Jun-2002 | 13.4 | 16.0 | 12.9 | 15.94 | 10 | 3 |
| Jul-2002 | 11.2 | 9.7 | 8.3 | 16.82 | 14 | 3 |
| Aug-2002 | 9.0 | 13.5 | 11.1 | 16.22 | 12 | 3 |
| Sep-2002 | 8.2 | 10.6 | 8.9 | 16.66 | 12 | 3 |
| Oct-2002 | 7.5 | 10.7 | 9.0 | 16.64 | 12 | 3 |
| Nov-2002 | 6.9 | 10.5 | 8.9 | 16.66 | 12 | 3 |
| Dec-2002 | 5.9 | 9.2 | 7.9 | 16.93 | 14 | 3 |
| Jan-2003 | 5.7 | 10.0 | 8.5 | 16.76 | 13 | 3 |
| Feb-2003 | 7.5 | 11.3 | 9.5 | 16.54 | 11 | 3 |
| Mar-2003 | 8.0 | 13.4 | 11.0 | 16.23 | 9 | 3 |

*Notes:* *(1) Average Stage is calculated using stage elevations at three stations on the sampling date*
*(2) Highlighted values indicate months when exceedances occurred*

# Figure 1. STA-1W Structures & Flow*

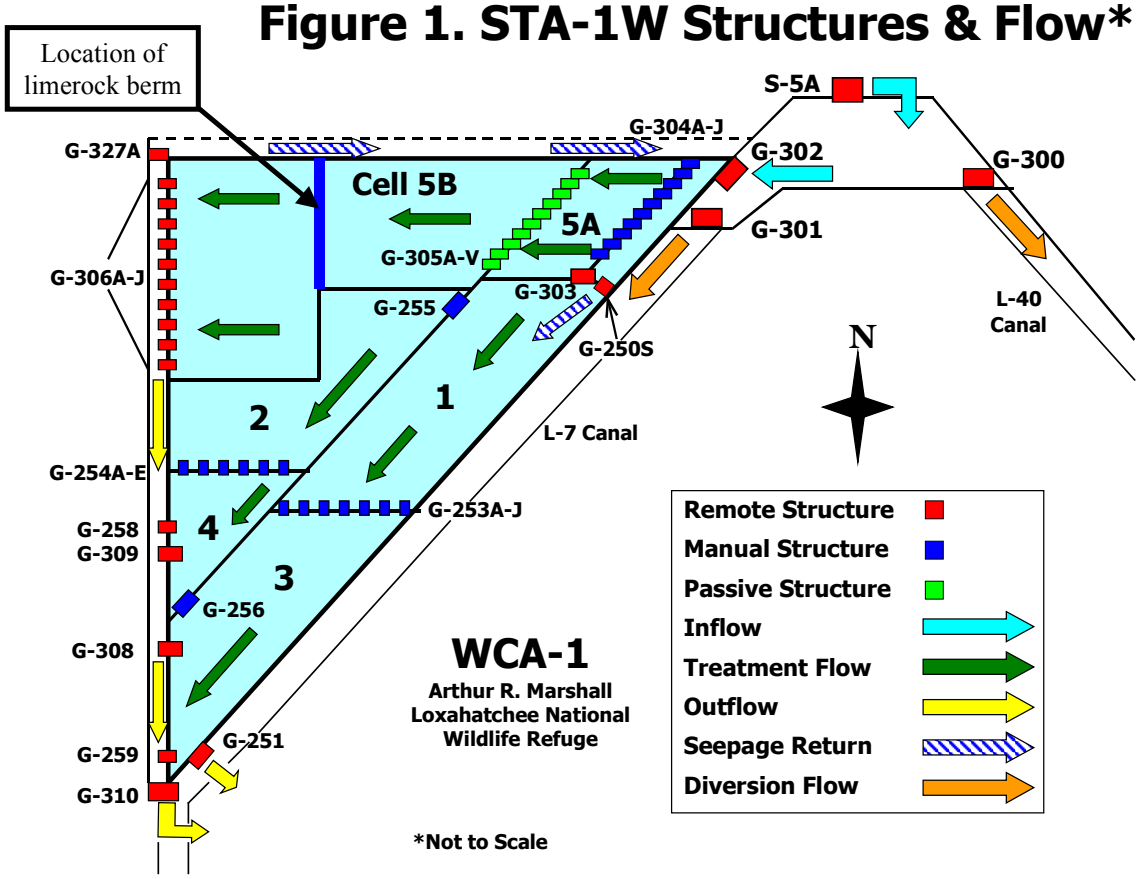

**Table 2. Hydrological Conditions and Total Phosphorus Conditions in the A.R.M. Loxahatchee National Wildlife Refuge for June and July 2002.**

| | | | | | | Rainfall (inches), Flows (cfs) and TP Concentrations (ug/L) | | | | | | | | | | | | Stage ( ft. NGVD29) | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Date** | **Rainfall** | **S5A** | **S5A** | **G300** | **G300** | **G301** | **G301** | **Acme 1** | **Acme 1** | **Acme 2** | **Acme 2** | **G302** | **G302** | **G251** | **G251** | **G310** | **G310** | **S 1-8C** | **S 1-7** | **S 1-9** |
| | **at S5A** | Inflow to | TP | Inflow to | TP | Inflow to | TP | Inflow to | TP | Inflow to | TP | Inflow to | TP | Inflow to | TP | Inflow to | TP | | | |
| | (inches) | Dist. Works | | L7 Canal | | L40 Canal | | L40 Canal | | L40 Canal | | STA1W | | L7 Canal | | L7 Canal | | | | |
| 1-Jun | | | | | | | | | | | | | | | | | | 14.22 | 15.8 | 15.46 |
| 2-Jun | | | | | | | | | | | | | | | | | | 14.07 | 15.78 | 15.44 |
| 3-Jun | 1.39 | 221.72 | | | | | | | | | | 187.55 | | | | 166.52 | | 13.94 | 15.76 | 15.42 |
| 4-Jun | | 554.88 | 98 | | | | | | | | | 384.6 | | | 29 | 433.67 | 29 | 13.87 | 15.75 | 15.4 |
| 5-Jun | | 591.12 | | | | | | | | | | 504.03 | | | | 523.4 | | 13.92 | 15.73 | 15.38 |
| 6-Jun | 0.25 | 536.95 | | | | | | | | | | 455.67 | | | | 541.79 | | 14.07 | 15.85 | 15.41 |
| 7-Jun | 0.21 | 587.19 | | | | | | | | | | 493.44 | | | | 518.82 | | 14.26 | 16.1 | 15.47 |
| 8-Jun | 0.018 | | | | | | | | | | | | | | | 88.99 | | 14.48 | 16.15 | 15.5 |
| 9-Jun | | | | | | | | | | | | | | | | | | 14.49 | 16.16 | 15.54 |
| 10-Jun | | | | | | | | | | | | | | | | | | 14.46 | 16.12 | 15.54 |
| 11-Jun | 0.4 | | | | | | | | | | | | | | 38 | | 23 | 14.47 | 16.11 | 15.57 |
| 12-Jun | 0.6 | | | | 99 | | 80 | | | | | | 80 | | | | | 14.51 | 16.14 | 15.73 |
| 13-Jun | 0.01 | 53.83 | | | | | | | | | | 34.83 | | | | | | 14.61 | 16.19 | 15.83 |
| 14-Jun | 0.21 | 617.35 | | | | | | | | | | 439.48 | | | | | | 14.78 | 16.26 | 15.9 |
| 15-Jan | 0.23 | 633.01 | | | | | | | | | | 489.91 | | | | 402.95 | | 15.1 | 16.35 | 16 |
| 16-Jun | 0.79 | 462.52 | | | | | | | | 45.42 | | 363.97 | | | | 355.66 | | 15.24 | 16.36 | 16 |
| 17-Jun | 0.06 | 1995.87 | | | | | | 42.17 | 80 | 56.08 | 94 | 1381.7 | | | | 759.87 | | 15.42 | 16.39 | 16 |
| 18-Jun | | 2274.06 | | | | | | 39.7 | | 59.68 | | 1853.85 | | | 27 | 1157.62 | 26 | 15.48 | 16.35 | 15.98 |
| 19-Jun | 1.15 | 953.83 | | | | | | 40.94 | | 55.68 | | 856.63 | | | | 460.97 | | 15.53 | 16.32 | 15.95 |
| 20-Jun | 1.15 | 2192.37 | | | | | | | | 64.85 | | 1659.01 | | | | 889.61 | | 15.58 | 16.29 | 15.93 |
| 21-Jun | 0.76 | 2644.24 | | 97.81 | | 62.35 | | 42.28 | | 77.4 | | 1739.05 | | | | 1602.04 | | 15.79 | 16.44 | 16.11 |
| 22-Jun | 0.02 | 3172.84 | | 229.32 | | 199.67 | | | | 62.3 | | 2156.67 | | | | 2137.63 | | 15.95 | 16.43 | 16.09 |
| 23-Jun | 0.33 | 2565.8 | | 10.5 | | | | | | | | 2086.3 | | | | 2362.99 | | 16.03 | 16.41 | 16.07 |
| 24-Jun | 0.87 | 3384.45 | | 111.49 | | 278.35 | | 41.17 | | 71.68 | | 2379.88 | | | | 2317.86 | | 16.12 | 16.4 | 16.08 |
| 25-Jun | 0.22 | 3736.14 | 203 | 312.09 | | 893.07 | | 57.44 | | 79.21 | | 1918.08 | | 32.24 | 49 | 2337.26 | 27 | 16.19 | 16.39 | 16.07 |
| 26-Jun | | 3372.23 | | 603.39 | 240 | 556.83 | 232 | 41.85 | | 53.9 | | 1612.25 | 224 | 81.64 | | 2006.18 | | 16.28 | 16.39 | 16.06 |
| 27-Jun | | 2382.44 | | | | 54.22 | | | | 56.74 | | 1871.14 | | 142.72 | | 2530.88 | | 16.33 | 16.38 | 16.06 |
| 28-Jun | | 1379.44 | | | | | | 37.36 | | 48.66 | | 931.24 | | 156.89 | | 2620.27 | | 16.37 | 16.38 | 16.08 |
| 29-Jun | 0.01 | 473.3 | | | | | | | | | | 297.78 | | 215.11 | | 2464.51 | | 16.35 | 16.36 | 16.11 |
| 30-Jun | 0.91 | 1295.4 | | | | | | | | | | 992.13 | | 196.11 | | 2114.07 | | 16.34 | 16.35 | 16.13 |
| 1-Jul | 1.2 | 2017.15 | | | | | | 105.92 | 85 | 135.64 | 111 | 1368.83 | | 176.72 | | 2140.48 | | 16.38 | 16.38 | 16.14 |
| 2-Jul | 0.01 | 2588.77 | 164 | | | | | 14.76 | | 37.56 | | 2090.8 | | 160.12 | 27 | 2178.56 | 32 | 16.42 | 16.41 | 16.17 |
| 3-Jul | 1.04 | 1516.08 | | | | | | | | 55.06 | | 1214.13 | | 124.73 | | 2254.73 | | 16.45 | 16.41 | 16.22 |
| 4-Jul | | 1047.13 | | | | | | | | | | 781.52 | | 134.32 | | 2118.55 | | 16.44 | 16.4 | 16.22 |
| 5-Jul | 0.12 | 863.26 | | | | | | | | 56.49 | | 662.92 | | 101.92 | | 1703.34 | | 16.43 | 16.39 | 16.21 |
| 6-Jul | 0.86 | 380.9 | | | | | | 42.98 | | 54.83 | | 299.28 | | 192.52 | | 1368.7 | | 16.46 | 16.4 | 16.24 |
| 7-Jul | 0.09 | 1397.65 | | | | | | | | | | 1086.57 | | 178.38 | | 994.84 | | 16.49 | 16.42 | 16.3 |
| 8-Jul | 1.94 | 1791.64 | | | | | | 42.23 | | 70.69 | | 1384.67 | | 166.1 | | 983.03 | | 16.53 | 16.5 | 16.35 |
| 9-Jul | 0.62 | 2696.86 | 137 | | | | | 106.24 | | 178.24 | | 2028.86 | | 159.13 | 24 | 1448.81 | 39 | 16.62 | 16.58 | 16.4 |
| 10-Jul | 0.72 | 2936.81 | | | 155 | | 165 | 147.05 | | 234.88 | | 2268.6 | 171 | 176.57 | | 1876.19 | | 16.67 | 16.63 | 16.47 |
| 11-Jul | 0.13 | 2477.81 | | | | | | 57.31 | | 107.03 | | 2072.64 | | 160.05 | | 2178.96 | | 16.69 | 16.69 | 16.48 |
| 12-Jul | 1.28 | 2043.36 | | | | | | 152.61 | | 194.89 | | 1575.44 | | 125.36 | | 2574.7 | | 16.76 | 16.81 | 16.54 |
| 13-Jul | | 2595.98 | | | | | | 152.59 | | 202.98 | | 1999.31 | | 120.97 | | 2408.65 | | 16.91 | 16.94 | 16.71 |
| 14-Jul | | 1315.41 | | | | | | 104.19 | | 133.94 | | 1180.38 | | 82.29 | | 2382 | | 16.91 | 16.91 | 16.69 |
| 15-Jul | 0.01 | 452.67 | | | | | | 63.17 | | 80 | | 471.92 | | 80.56 | | 2087.17 | | 16.91 | 16.88 | 16.68 |
| 16-Jul | 0.01 | 717.13 | 132 | | | | | 58.19 | | 74.98 | | 588.16 | | 44.88 | 26 | 1000.83 | 34 | 16.9 | 16.87 | 16.68 |
| 17-Jul | 0.45 | 623.52 | | | | | | 41.14 | | 52.65 | | 515.5 | | 149.01 | | 476.39 | | 16.87 | 16.89 | 16.67 |
| 18-Jul | 0.41 | | | | | | | 107.83 | | 140.93 | | | | 74.66 | | 385.81 | | 16.9 | 16.92 | 16.68 |
| 19-Jul | | 483.98 | | | | | | 149.79 | | 195.1 | | 381.83 | | 75.1 | | 330.95 | | 16.92 | 16.89 | 16.69 |
| 20-Jul | | | | | | | | 50.48 | | 64.08 | | | | | | | | 16.86 | 16.85 | 16.66 |
| 21-Jul | 0.014 | | | | | | | | | | | | | | | | | 16.81 | 16.82 | 16.62 |
| 22-Jul | | 415.51 | | | | -0.04 | | 41.17 | | 52.24 | | 354.16 | | | | 30.94 | | 16.77 | 16.8 | 16.59 |
| 23-Jul | | 213.67 | 169 | -16.04 | | | | 46.29 | | 19.7 | | 145.27 | | | 39 | 283 | 123 | 16.71 | 16.78 | 16.55 |
| 24-Jul | | | | -57.64 | 85 | -239.65 | 248 | 46.2 | | 35.88 | | | 413 | | | | | 16.66 | 16.74 | 16.52 |
| 25-Jul | 0.021 | | | | | -320.01 | | 42.75 | | 55.54 | | | | | | | | 16.6 | 16.71 | 16.48 |
| 26-Jul | | | | -189.43 | | -56.39 | | 33.06 | | 37.49 | | | | | | 307.18 | | 16.53 | 16.68 | 16.44 |
| 27-Jul | | | | -355.74 | | | | | | | | | | | | | | 16.47 | 16.65 | 16.4 |
| 28-Jul | | | | -352.48 | | | | | | | | | | | | | | 16.41 | 16.61 | 16.36 |
| 29-Jul | | 579.89 | | -106.88 | | | | | | | | 294.16 | | 70.07 | | | | 16.37 | 16.58 | 16.32 |
| 30-Jul | | 856.32 | | | | | | | | | | 502.37 | | 140.54 | 30 | 237.77 | 97 | 16.34 | 16.55 | 16.29 |
| 31-Jul | | 851.32 | | | | | | | | | | 510.74 | | 127.19 | | 255.52 | | 16.29 | 16.53 | 16.26 |

Table 3. Phosphorus levels at individual monitoring stations in the Refuge.

| Month_Col | LOX3 | LOX4 | LOX5 | LOX6 | LOX7 | LOX8 | LOX9 | LOX10 | LOX11 | LOX12 | LOX13 | LOX14 | LOX15 | LOX16 | Geomean |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Jan-01 | | | | 0.006 | 0.011 | 0.011 | | | 0.009 | 0.004 | 0.008 | 0.007 | | 0.005 | 7.21 |
| Feb-01 | | | | 0.008 | 0.019 | 0.013 | | | 0.009 | 0.007 | 0.011 | 0.007 | 0.007 | 0.01 | 9.57 |
| Mar-01 | | | | | | | | | | 0.017 | 0.022 | | | | 19.34 |
| Apr-01 | | | | | | | | | 0.014 | 0.011 | 0.011 | 0.014 | 0.009 | 0.011 | 11.53 |
| May-01 | | | | | | | | | | 0.021 | 0.016 | | | | 18.33 |
| Jun-01 | | | | 0.013 | 0.017 | 0.02 | | | 0.018 | 0.013 | 0.017 | 0.02 | 0.009 | 0.013 | 15.11 |
| Jul-01 | | 0.011 | | 0.013 | | 0.009 | 0.01 | 0.009 | 0.016 | 0.01 | 0.017 | 0.012 | 0.01 | 0.011 | 11.38 |
| Aug-01 | 0.013 | 0.015 | 0.012 | 0.009 | 0.01 | 0.011 | 0.012 | 0.01 | 0.007 | 0.008 | 0.01 | 0.009 | 0.007 | 0.01 | 9.99 |
| Sep-01 | 0.011 | 0.013 | 0.014 | 0.007 | 0.011 | 0.01 | 0.009 | 0.008 | 0.007 | 0.009 | 0.012 | 0.007 | 0.008 | 0.012 | 9.60 |
| Oct-01 | 0.009 | 0.01 | 0.009 | 0.006 | 0.011 | 0.009 | 0.008 | 0.008 | 0.012 | 0.008 | 0.011 | 0.008 | 0.008 | 0.008 | 8.80 |
| Nov-01 | 0.006 | 0.006 | 0.01 | 0.006 | 0.008 | 0.0085 | 0.007 | 0.0085 | 0.01 | 0.0035 | 0.0085 | 0.0025 | 0.005 | 0.0085 | 6.57 |
| Dec-01 | 0.006 | 0.006 | 0.009 | 0.006 | 0.007 | 0.008 | 0.006 | 0.008 | 0.009 | 0.006 | 0.024 | 0.007 | 0.006 | 0.006 | 7.48 |
| Jan-02 | 0.011 | 0.007 | 0.007 | 0.005 | 0.006 | 0.008 | 0.005 | 0.005 | 0.009 | 0.004 | 0.008 | 0.006 | 0.005 | 0.007 | 6.41 |
| Feb-02 | 0.007 | 0.009 | 0.01 | 0.007 | 0.009 | 0.008 | 0.008 | 0.008 | 0.009 | 0.007 | 0.008 | 0.006 | 0.006 | 0.008 | 7.77 |
| Mar-02 | 0.008 | 0.008 | 0.013 | 0.006 | 0.007 | 0.008 | 0.006 | 0.006 | 0.01 | 0.005 | 0.008 | 0.007 | 0.005 | 0.008 | 7.26 |
| Apr-02 | | | 0.01 | 0.007 | 0.009 | 0.008 | 0.008 | | 0.007 | 0.009 | 0.007 | 0.005 | 0.007 | 0.007 | 7.52 |
| May-02 | | | | | | | | | | 0.007 | | 0.013 | 0.011 | | 10.00 |
| Jun-02 | | 0.02 | | 0.012 | 0.014 | 0.013 | | | 0.013 | 0.009 | 0.014 | 0.015 | 0.01 | 0.017 | 13.37 |
| Jul-02 | 0.014 | 0.021 | 0.011 | 0.009 | 0.01 | 0.01 | 0.012 | 0.011 | 0.013 | 0.009 | 0.011 | 0.014 | 0.006 | 0.012 | 11.22 |
| Aug-02 | 0.013 | 0.009 | 0.01 | 0.007 | 0.011 | 0.007 | 0.009 | | 0.011 | 0.008 | | 0.007 | 0.008 | 0.01 | 8.99 |
| Sep-02 | | 0.014 | | 0.006 | 0.008 | 0.009 | 0.007 | 0.007 | 0.01 | 0.008 | 0.016 | 0.007 | 0.005 | 0.007 | 8.20 |
| Oct-02 | | 0.009 | 0.009 | 0.006 | 0.009 | 0.009 | 0.007 | 0.007 | 0.008 | 0.009 | | 0.005 | 0.005 | 0.009 | 7.49 |
| Nov-02 | | 0.009 | 0.007 | 0.005 | 0.006 | 0.006 | 0.004 | 0.012 | 0.009 | 0.009 | | 0.006 | 0.006 | 0.007 | 6.87 |
| Dec-02 | 0.007 | 0.006 | 0.006 | 0.006 | 0.006 | 0.007 | 0.004 | 0.004 | 0.007 | 0.006 | 0.008 | 0.005 | 0.006 | 0.006 | 5.90 |